SUNSPOTS AND WEATHER

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The possibility that sunspots affect weather, and might be made a basis for long-range forecasting, has been recognized for many years, and their effect on "radio weather" is well known. Recently there seems to be renewed interest in this matter, and it is sometimes said that the subject has become "respectable" among meteorologists. The purpose of this note is to point to evidence that *no* phenomenon having a period in the vicinity of 10 years has any great effect on weather for at least some weather elements in some places. A single example will be given.

Norton and Brier [1] studied persistence in Greenwich monthly mean temperatures. One hundred years of data, 1764 to 1863, were used and the correlation between months was computed for each interval from one to twelve months inclusive, separately for each of the twelve possible antecedent (or subsequent) months. The 144 correlations, each based on 99 pairs of observations, of which the antecedent fell in the years 1764 to 1862 inclusive, were taken as data for statistical analysis. In brief, it was found that the correlation decreased curvilinearly with increasing interval, as would be expected a priori, falling from an average of about 0.3 for consecutive months to about half that for months one year apart, and that there was an annual cyclic variation in each of the twelve intervals studied. These twelve cycles were in phase with respect to the subsequent (but not the antecedent) month of the pair, which could be adequately represented by an annual sine wave plus the first harmonic (that is, a wave of period 6 months), amounting to deviations from the average correlation for a given interval of about 0.10 when August or September was the subsequent month, and −0.14 for January, both the decrease with increasing interval and the cyclic variation being statistically beyond reasonable doubt.

Table 1 gives the smoothed values of the 144 correlations, that is, values estimated from the fitted curves of decrease with increasing interval and cyclic variation with the twelve subsequent months. Of course, the sampling reliability of these smoothed values does not justify retention of three decimals. Though they are improved compared to the unsmoothed correlations, which were subject to a sampling standard error averaging about 0.099, they are yet subject to an average sampling error of about 0.0194 (not 0.088 as stated by Norton and Brier [1]).

It is of particular interest, in connection with possible effects of sunspots, that many of these correlations are practically zero, and even for consecutive months they reach a low of 0.158 for December and January. Hence, knowledge of December monthly mean temperatures will account for only about 2.5 percent of the variation in the immediately succeeding January mean temperatures. Even if it were supposed that the estimated correlation of 0.158 was seriously too low as the result of sampling errors, its 1 percent upper confidence limit is only 0.214. It follows that there is less than one chance in a hundred that the December monthly mean temperature at Greenwich accounts for as much as 4.6 percent of the variance of the immediately subsequent January mean temperature.

To make such correlations bear upon the possibility of a relation between sunspots and weather it is only necessary to recognize that the sunspot cycle extends over several years and that its effect upon terrestrial weather must result in a correlation between observations which are

TABLE 1.—*Smoothed correlations*

Antecedent month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
January	0.004	0.174	0.193	0.221	0.236	0.238	0.241	0.245	0.234	0.187	0.109	0.034
February	−.007	.020	.232	.255	.265	.262	.260	.259	.243	.191	.108	.028
March	−.013	.009	.077	.294	.299	.291	.284	.278	.257	.200	.112	.027
April	−.014	.004	.066	.139	.338	.325	.313	.302	.276	.214	.121	.032
May	−.010	.003	.060	.128	.183	.364	.347	.331	.300	.233	.135	.041
June	−.001	.007	.060	.123	.172	.209	.385	.365	.328	.257	.154	.055
July	.013	.016	.064	.122	.166	.199	.231	.404	.362	.286	.178	.074
August	.032	.030	.073	.126	.166	.193	.220	.249	.401	.320	.207	.098
September	.056	.049	.087	.135	.170	.192	.214	.238	.247	.358	.241	.126
October	.085	.073	.106	.149	.179	.196	.214	.233	.236	.204	.280	.160
November	.119	.102	.130	.168	.193	.205	.218	.232	.230	.193	.125	.199
December	.158	.136	.159	.192	.212	.219	.227	.236	.229	.188	.114	.045

separated by a few months or less. In particular, if the sunspot cycle imposed on terrestrial temperatures any such effect as is sometimes supposed, namely that higher sunspot numbers mean higher terrestrial temperatures, the effect upon any December and the immediately following January would be nearly the same because one month is so small a part of the sunspot cycle, which averages about 11 years.

In fact, to the extent that deviations of these monthly temperatures from their respective long-time means or trends were due to the effect of any cause which changes slowly through a cycle lasting roughly 10 years, (or longer up to at least a hundred years, thus including the double sunspot cycle), these deviations would be almost perfectly correlated. For example, the 1-month lag correlation for a quantity which follows a sine wave with an 11-year period is 0.99887. For a function which increases linearly through 11 years and then returns instantaneously to its original value, the 1-month lag correlation is 0.95523. This makes it plain that the failure to find a substantial correlation of December with January reflecting some cyclic cause with a period of roughly 10 years is not appreciably due to the length of the interval (1 month) between data.

It follows, that at the 1 percent confidence level, *no* such cause accounted for as much as 5 percent of the variance of January mean temperatures at Greenwich during the 99 years 1765 to 1863 inclusive. Meteorologists who find themselves thinking seriously of sunspots as an important cause of terrestrial weather will be well advised to bear this correlation in mind, and to try to develop a hypothesis of sunspot influence sufficiently detailed to include little or no influence on some important weather elements at some locations, before they spend more effort on direct search for sunspot-weather relationships.

REFERENCE

1. H. W. Norton and G. W. Brier, "Persistence in London Temperatures," U. S. Weather Bureau *Research Paper No. 10*, 1944, 9 pp.

CORRECTION

Vol. 85, No. 1, p. 26, table 1: The temperature of −55° F. listed for Boonville, N. Y. was not officially accepted.